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The COVID-19 pandemic: A threat to forest and wildlife conservation in Bangladesh?

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ABSTRACT

The global pandemic due to COVID-19 (SARS-COV-2) has brought significant disruption to society and the environment. In this study, evidence from newspapers, social media, remote sensing and organisational data were used to assess the impact of national lockdown on forest and wildlife conservation, including the forest-dependent people in Bangladesh. The nationwide lockdown worsened the non-forest income-generating activities of the forest-dependent communities leading to increased pressure on neighbouring forests. Global Land Analysis and Discovery (GLAD) data reveal spurred deforestation alerts in May 2020, and about 222 ha forest area had been cleared during January to October 2020, which is 8% more than the whole year of 2019. Despite some positive information about free movement of wildlife in the forest, a total of 112 animals were killed, which is 28 times more than that of the same period in 2019. At the same time, wildlife rescuing plummeted by more than 40%. Complete banning of tourism activities brought a significant reduction in income and employment, leading to collapse of the tourism industry. Lack of tourists, on the other hand, brought a blessing to the wildlife, allowing them to roam freely. Both air and water quality were improved in Dhaka city, and increased aquatic wildlife activities were recorded in some major rivers. The forest department's revenue shrank substantially during the lockdown period than that of the previous year. This study highlighted a substantial impact on all aspects of forest and wildlife conservation and on the forest-dependent people, which might be a pitfall for attaining the achievements of national and international conservation goals and treaties. Furthermore, the research highlighted policy implications that would be effective in minimizing pandemic-wrought threats and maintain and foster conservation activities in different forests in Bangladesh.

1. Introduction

Since the beginning of 2020, the world has been facing severe disruption in all aspects of life, including the economy, due to the spread of the acute respiratory syndrome (SARS-CoV-2), which is now known as coronavirus disease 2019 (COVID-19) (Gorbalenya et al., 2020; He et al., 2020a; Zhu et al., 2020). As of January 22, 2020, worldwide, more than 95 million cases were detected, and more than 3 million people died in all countries within a year (WHO, 2021). Drastic measures have been taken globally to curb the spread of this disease, including international travel restrictions and placing hundreds of millions of people under lockdown (Hamzelou, 2020; Zhang et al., 2021). Since the first lockdown was imposed in Wuhan, China, global lockdowns were put in place and subsequently extended. Higher restrictions were imposed continuously, especially in the northern hemisphere to tackle the new COVID-19 variant (Grant and Hunter, 2021;Liu et al., 2021). Even without a total

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lockdown, measures were taken throughout the year 2020 to close schools and workplaces, and to impose other safety restrictions, such as social distancing and wearing of masks. These draconian measures had enormous socio-economic impacts.

With thousands of people dying and getting infected daily, COVID-19 has been one of the main threats to humankind (Karlinsky and Kobak, 2021; Maleki et al., 2020). The main priorities of governments and policymakers in all countries are now to prevent this fast-spreading disease and to save people's life. Hence, the environmental impacts associated with this pandemic and the behavioural changes of human beings are becoming overlooked or have hardly been considered. Although COVID-19 has been an extensive threat to human existence, it has brought some direct and indirect positive changes in our environment and ecosystem, primarily because of widespread lockdown halted transport and industry. Among the positive environmental consequences, the reduction of air pollution, greenhouse gas emission, noise pollution, and clean beaches are notable in different countries (Bao and Zhang, 2020; Dantas et al., 2020; (He, Pan and Tanaka, 2020b)Kerimray et al., 2020; Muhammad et al., 2020; Wang and Su, 2020; Zambrano-Monserrate et al., 2020). On the other hand, extensive uses of protective measures such as masks or gloves also pollute the environment by increasing both organic and inorganic waste (Zambrano-Monserrate et al., 2020).

While several studies have reported the environmental consequences of this pandemic from various countries, the pandemic impacts on the total environment, particularly on the exploitation of various forest resources are rarely reported, especially in developing countries. For example, deforestation and forest degradation, as from illegal logging, poaching, mining, and land grabbing are likely to be the predicted outcomes of long-term lockdown and lowered forest monitoring systems (FAO, 2020a; Troëng et al., 2020). The largest rainforest, the Amazon, has experienced a deforestation rate of 30% higher during this pandemic compared to the same time last year (Gardiner, 2020; Spring, 2020). In Indonesia, the government has abandoned checking the legality of timber exports order to boost the fragile economy, which will undoubtedly increase illegal logging and accelerate the deforestation of the world's third-largest tropical rain forest (Farand, 2020). Several African countries have reported the rise of bushmeat poaching and trafficking resulting from this pandemic induced lockdown, which is accelerating poverty due to decreased tourism activities (Ghosal and Casey, 2020; Newburger, 2020; Price, 2020). A surge in poaching of wildlife and deforestation in several Asian countries has also been reported, where a large portion of the population is forced to depend mostly on forest resources for their livelihoods due to this pandemic (Ghosal and Casey, 2020; Troëng et al., 2020). Many endangered animals, such as rhinos, elephants, jaguars, and pumas, are particularly vulnerable in many regions because of the economic collapse and reduced monitoring from conservation and security personnel that has resulted from this unprecedented lockdown (Oliphant and Thornycroft, 2020; Roth, 2020; Maron, 2020a, 2020b). Therefore, a holistic view of the COVID-19 impacts on forest environments and related communities is a timely demand and has its own scientific merit.

Bangladesh is one of the most densely populated developing countries in the world and has been hit hard by this ongoing global pandemic. According to Worldmeters (2021), Bangladesh has experienced enormous community transmission of the deadly COVID-19. So far 531,326 positive cases have been reported since the first case on the 8th of March (Bodrud-Doza et al., 2020; WHO, 2020b). To tackle the initial spread of the virus, the government of Bangladesh imposed a lockdown from 26th March to 30th May 2020 (Shammi et al., 2020). This measure has been disastrous to the country's health, economy and environment, including the forest-dependent communities and wildlife. It needs to be noted that, with forest cover at 12.8% of the total land area, Bangladesh is one of the countries with the lowest per capita forestlands in the world (Iftekhar and Hoque, 2005; GOB, 2019; Reza and Hasan, 2019). On the contrary, it is highly rich in biodiversity because of the geographical location and climatic conditions (Ahmed et al., 2008; Rahman, 2015; Reza and Hasan, 2019). Moreover, about 19 million people are directly and indirectly dependent on forest resources and thus create a severe pressure on forest resources (Rahman and Ahmed, 2016). Reddy et al. (2016) found that Bangladesh has already lost 39% of its natural forest since 1930, where forests in the Chattogram hill tracts have faced the most deforestation, followed by sal forests in the northern region. However, recent estimates by Potapov et al. (2017) suggest that total tree cover in Bangladesh has increased by 4.3% within 15 years from 2000, with a 12.9% increase in the tree outside the forest (i.e., village forest). Satellite image analysis has revealed that the dense forest area around the Rohingya refugee camp reduced to almost half (from 8531 ha to 4498 ha) within two years from 2016 to 2018, whereas the settlement increased from 271 ha to 2679 ha (Ahmed et al., 2019). Moreover, the development program of the Bangladesh government has also exacerbated deforestation on forest land between Mirsharai of Chattogram and Teknaf of Cox's Bazar (Yousuf, 2019). An analysis by WCS (2018) of social media and newspaper reports reveals that between 2012 and 2016, a total of 249 wildlife species were identified as the victims of poaching and illegal trade at a rate of 4.15 per month. With ongoing forest degradation and deforestation, the COVID-19 pandemic-wrought socio-economic recession is believed to have exacerbated both short and long-term destruction of forest and natural resources.

The COVID-19 pandemic has brought substantial turmoil in all the socio-economic aspects in Bangladesh with an increasing impact on environmental systems, especially to the forest and forest-dependent people. The consequences of lockdown measures are likely to impede or alter the usual interaction between humans and forests, including wildlife. Hence, this study aims to investigate the impact of the COVID-19 lockdown on different forests, wildlife, environment, and forest-dependent people in Bangladesh. This study further provides policy recommendations to protect and conserve forests and wildlife resources from damages caused by the COVID-19 pandemic.

2. Materials and methods

2.1. Forest and wildlife conservation in Bangladesh

The natural forests of Bangladesh mainly consist of the world's largest mangrove forest (the Sundarbans), tropical moist deciduous (Sal forest), tropical semi-evergreen (hill forest) and freshwater swamp forest (Fig. 1) (Iftekhar, 2006; GOB, 2019(Rahman et al., 2020)). Besides, the tree plantations throughout the country, including homestead agroforestry and social forestry activities, and the mangrove plantation in the coastal belt, are often regarded as village forests and coastal forests simultaneously (GOB, 2019). The conservation of forests (except village forest) and wildlife throughout the country is maintained by the Bangladesh Forest Department (BFD) under the Ministry of Environment, Forest and Climate Change. The biodiversity in the forested land in Bangladesh is very rich and diverse. The wildlife diversity comprises about 1619 animal species, including 138 mammals, 566 birds, 167 reptiles, 49 amphibians, 253 freshwater fishes, 141 crustaceans, and 305 butterfly species (IUCN Bangladesh, 2015; Mukul et al., 2020b; Mukul et al., 2018). The latest Bangladesh forest inventory (2016 - 19) found 392 tree species from all over the country, among which 232 major species were from the village forests, representing outstanding floral diversity (GOB, 2019; Mukul et al., 2016). To conserve and protect the biodiversity and wildlife in their natural habitat, the BFD has set aside 49 protected areas with an area of 637,875 ha, accounting for 4.26% of the total land of Bangladesh (BFD, 2020(Rahman et al., 2021)). The department has a separate resolute Wildlife Crime Control Unit (WCCU) to prevent poaching, capturing or trading wildlife in any part of Bangladesh. They also work with other national and international law enforcement agencies to prevent the wildlife trade (Faroque and South, 2020).

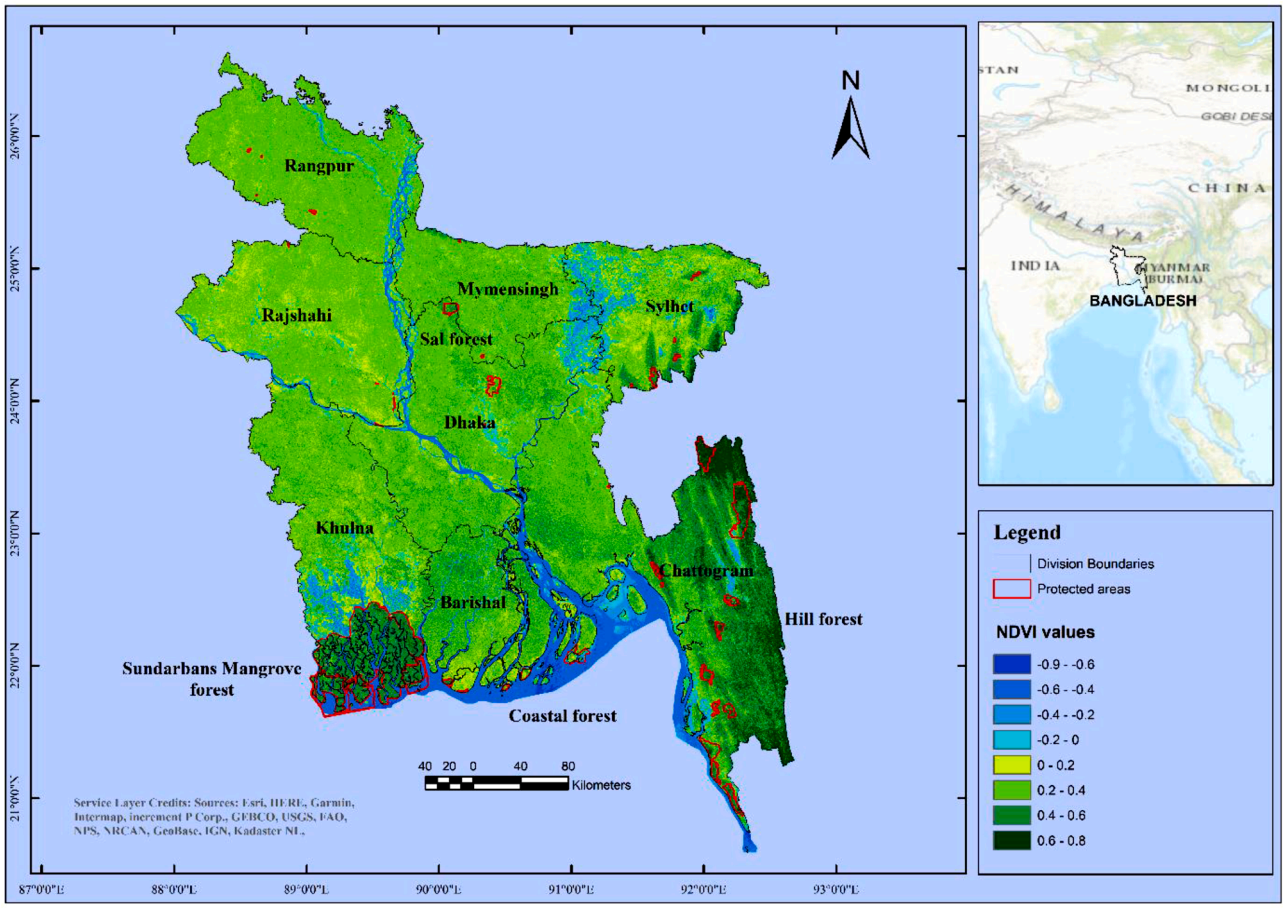

Fig. 1. Distribution of different forests in Bangladesh. The map represents NDVI (Normalised Difference Vegetation Index) values from the Landsat composites in 2019 derived from forest change dataset by Hansen et al. (2016), with higher values (green) indicates high density forest, while lower (blue) indicates surface water and yellow indicates agriculture, built-up areas and other land uses (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

2.2. Data collection

The impact of the pandemic on the forest and environment in Bangladesh was collected from gray literature such as research reports, working papers and reports from the Forest Department, Bangladesh and media reports with the combination of three categories of codes related to COVID-19, impact, and geographical area (Table 1). As the information from the scientific literature is scarce, the content analysis method was followed to analyze information from newspapers and social media. The media reports were collected after the COVID-19 lockdown imposed from 26th March up to 30th June 2020. The same period in 2019 was selected as a baseline to find and compare the impact. The selected period also covered sam season in Bangladesh; therefore, sesonal effects such as cyclones, storms, floods, or monsoons on wildlife crimes, tourism activities, and environmental variables were normalised. For example, the number of migratory birds in winter is high in Bangladesh, which is likely to cause more bird poaching in winter than in other seasons (Khatun and Islam, 2018).

Table 1
Three categories of codes for literature and media search.

Corona virus	Impact	Geographical
COVID-19	Socio-economic consequences	Forest
Corona	Deforestation	Ecosystem
Lockdown	Wildlife/Wild plant	Environment
Pandemic	Tourism/ Eco-tourism	Protected areas
	Environmental Pollution/ air quality	Ecologically critical areas
	Forest product/price/revenue	Wildlife sanctuary
		National park

2.2.1. Newspaper media

Information was collected from formal and informal reports in local and global digital media, including newspapers. Media reporting is an essential tool for obtaining the problems and opinions of actors at the local level affecting the policy agenda and facilitating discussion (Kleinschmit, 2012; Rahman and Giessen, 2014). Three national newspapers were selected: a Bengali daily newspaper, *Prothom Alo*; an English daily newspaper, the *Daily Star*; and one online daily newspaper, the *Dhaka Tribune*.

2.2.2. Social media

Social media present the citizen's voices on a wide range of topics, including awareness of forests and the environment (Cabré-Olivé et al., 2017). During the COVID-19 pandemic, the use of social media has increased all over the world to disseminate news related to the pandemic (Pérez-Escoda et al., 2020; Saud et al., 2020). Therefore, information related to the impact of the pandemic on forests and the environment in Bangladesh were collected from social media, especially Facebook and Twitter, to collect. In the case of Facebook, the public pages and three closed group pages were searched: the Bangladesh Forest Department (BFD), the apex state department managing forest biodiversity in Bangladesh; Bangladesh Paribesh Andolon (BAPA), a civic movement platform to protect Bangladesh's environment; and the Wildlife Crime Control Unit of the Forest Department (WCCU). Members of these groups usually post relevant daily news. The codes were used as

hashtags in Twitter, along with the sampling timeframe. After obtaining the initial list of social media news, information was sorted manually, and duplicates were discarded. All the contents, including any external links to the primary evidence, were then analyzed and summarized.

2.2.3. Satellite data

Deforestation alert data and sentinel-5P data were collected using the Google Earth Engine platform from 1st January 2019 to 31st October 2020. Google Earth Engine (GEE), a cloud-based platform, provides open-access petabyte-scale historical satellite images and datasets for scientific analysis and visualization (Gorelick et al., 2017). The GEE platform enables users to analyze these free global imageries and datasets in a powerful way that requires minimal coding expertise and without any use of supercomputers (Tamiminia et al., 2020). The deforestation alert data were generally sourced from Global Land Analysis and Discovery (GLAD) (Hansen et al., 2016). It is a Landsat-based product, which produces real-time forest loss and updates deforestation daily across the tropics with an approximately 28 m spatial resolution. The confirmed daily number of deforestation alerts, encoded as 3 in the dataset, were used in the analysis. These alerts do not necessarily represent the actual deforestation; however, the confirmed loss is ensured by observing repeated loss within four observations or 180 days (Hansen et al., 2016).

The collected air quality data in the Google Earth Engine was originally retrieved from the Sentinel-5 Precursor (S5p) mission by the European space agency (ESA). This satellite-derived TROPOMI (TROPOspheric Monitoring Instrument) is a multispectral sensor that records reflectance of wavelengths of ozone (O_3), formaldehyde (HCHO), aerosols, carbon monoxide (CO), nitrogen oxide (NO_2), and sulfur dioxide (SO_2) at a spatial resolution of 7.0 × 3.5 km^2 and much improved 5.5 x 3.5 km^2 since 6th August 2019 (Veefkind et al., 2012). Near real-time version of the data were used along with filtering the administrative area of Dhaka city, Bangladesh. The gaseous molecules are presented as column density (mol m^{-2}), except for the Aerosol Absorption Index (AAI), which represents a qualitative index of the ratio of two wavelengths (354/388 nm) and is therefore unitless (ESA, 2020). It indicates changes in Rayleigh scattering in the UV spectral range, where positive values indicate the presence of UV-absorbing aerosol.

2.2.4. Forest revenue and air quality

Information on annual forest revenue was collected from the Forest Department, Bangladesh and daily data on fine particulate matter (PM2.5) was from the US embassy, measured in their office location in Baridhara, Dhaka, Bangladesh (Airnow, 2020).

3. Results

3.1. Socio-economic consequences

Any disturbances or degradation of the resources by a pandemic or natural disaster may create a substantial negative impact on the livelihoods of forest-dependent people. At the beginning of the COVID-19 pandemic, the livelihood of the people around the Sundarbans mangrove, coastal and village forest was much affected, not only by the pandemic itself but also by the super cyclone 'Amphan', which landed on 20th May 2020. The initial national lockdown aggravated the already distressed situation of these dependent communities by hindering their access to resources and income-generating activities. The sharp rise in the economic vulnerability of these communities, in turn, increased pressure on neighbouring natural areas. The ultimate impact on the forest is overexploitation, deforestation, and degradation of such natural resources by the people in the absence of disruption of economic opportunities (Irfanullah, 2020; Ruszczyk et al., 2020). However, apart from the coastal Sundarbans forests, this study did not find any reports on the sal, hill, and village forests.

Our study finds that various environmental stressors (e.g., cyclones, riverbank erosion, salinity intrusion, and floods) have already negatively impacted on people in the coastal Bangladesh by narrowing their livelihood options (Ahmed et al., 2019). It is reported that recent human- and nature-induced phenomena, like cyclone 'Amphan' and various government regulations, including a ban on fish and crab cultivation in breeding seasons, have created enormous difficulties for peoples' livelihoods (Mirza, 2020; Moniruzzaman, 2020). In many cases, these vulnerable people (e.g., farmers, fishers) suffer from food insecurity and a shortage of income. However, the COVID-19 pandemic has worsened the situation to an even more severe level by diminishing their income and restricting access to markets and resources. In addition, disruption of the supply chain has threatened the livelihoods of many farmers and reduced their livelihood options. This difficulty, in turn, putting them into the 'livelihood trap', a situation where there are no alternative legal livelihood strategies, which can sometimes force them to grab illegal livelihood activities (Ahmed et al., 2019).

The lives of nomadic indigenous communities such as the 'Bede' community members have come to a halt as fear of COVID-19 spread prevents them from earning their living by roaming around different localities. This traditional community lives by showing snake charming, monkey acrobatics, and magic tricks and selling herbal medicines, amulets, river oyster pearls, and talismans in different places. Hasina, a member of this community, described her misery in the following words:

"Our income sources have entirely closed as we do not go outside. We even fail to ensure one meal a day to our families. We will not survive if the government does not help us" (Bappi, 2020).

Even though, the pandemic has helped people to be innovative and resilient to cope with the new circumstances.

"The pandemic has offered a glimpse of renewed hope and increased resilience amongst communities. It has forced us to explore creative methods to sustain our livelihoods and social responsibilities" (ICCCAD, 2020).

There was always a fear, and afterwards, it became confirmed that this pandemic, coupled with natural disasters (flood, cyclone, and erosion), made people a lot more vulnerable. It was difficult for them to settle and earn their living, especially in coastal Bangladesh. It was reported that the targeted vulnerable population is still getting food and cash assistance for their livelihood support. However, the pandemic and impacts from a changing climate continue to show the importance of budgeting for supporting peoples' livelihood.

3.2. Deforestation

The GLAD deforestation alert services showed that the total number of deforestation alerts within 10 months in 2020 soared by 77% in comparison to 2019 (Fig. 2). During the lockdown in Bangladesh,

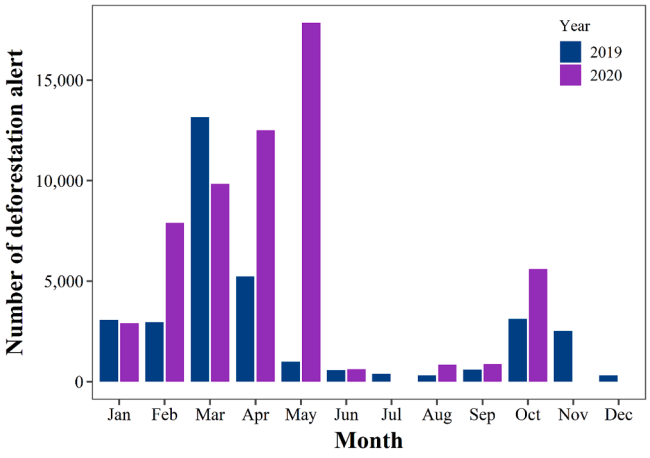

Fig. 2. Monthly total number of deforestation alert in Bangladesh in 2019 and 2020. N.B.: in 2020 up to October.

deforestation alerts increased by more than 2700% in May, and 40% more in April. However, there had also been signs of increasing deforestation before lockdown in February (166%) and March (3%), although less pronounced than during the lockdown. After lockdown, deforestation alerts were increased by 40% in October 2020, while it decreased only in July (98%) (Fig. 3).

The GLAD deforestation data revealed that about 222 ha additional forests was deforested in the first ten months of 2020 than 2019 (8% more than 2019). Although most of the deforestation happened in the hill forest in both years, about 141 ha (33% in 2020) area was deforested in the village forests. About 1842 ha (65% in 2020) was deforested in the hill forest, with an increase of 5% from 2019. The only exception was in the coastal forest, where deforestation decreased by 12 ha from 2019. The deforestation in Sal and the Sundarbans was relatively low. However, there was an increase in deforestation of about 43% in the Sal forest.

The media reports also revealed deforestation in 2019, mainly in the Cox's Bazar evergreen forest and the Gazipur Sal forest, however, there were no such reports during the pandemic. Among the four reported newspaper articles, two highlighted deforestation due to the settlement of the Rohingya people: almost 2500 ha of forest land had been cleared in the Taknaf and Ukhiya sub-districts, home of the hill forest in Bangladesh (Palma and Jinnat, 2019; Sultana, 2020). The enormous settlement of the Rohingya people caused severe destruction to the protected areas, including the Teknaf Wildlife Sanctuary, the Himchhari National Park and the Inani National Park, which has been very harmful to the environment, forest, and biodiversity. The deforested area is also a restricted route of the Asian Elephant in the Cox's Bazar district. A report also raised concern for future deforestation in the Shuknachhari forest, Cox's Bazar, where the Bangladesh ministry of Public Administration proposed to establish a civil service training academy and is demanding about 280 ha of forest land. Another report documented deforestation of the Sal forest, Gazipur, where industrialization fostered and reduced 10–11% of the forest area from 2000 (Mridha, 2019).

3.3. Wildlife

During the lockdown period in 2020, the number of reported animal fatalities more than doubled and, shockingly, animals killing was 28 times higher in 2020 than in the same period in 2019 (Fig. 4, Table 2). At the same time, the number of rescued wildlife declined by more than 40% during the lockdown period in 2020. These estimates excluded birds, of whom almost 1500 were rescued from different markets and houses by the WCCU team. However, only 3 birds were rescued in 2020, and around 600 birds were killed during the pandemic, with the greatest

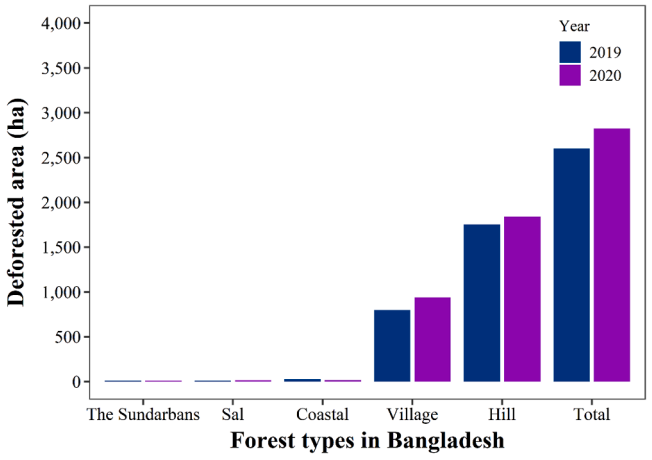

Fig. 3. Total deforested area in different forests of Bangladesh in 2019 and 2020. N.B.: in 2020 up to October.

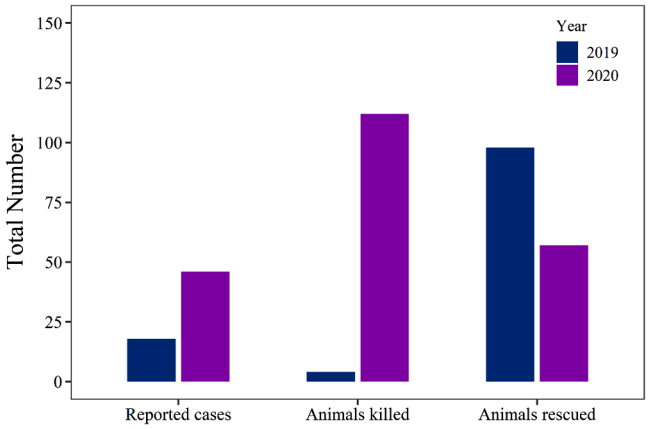

Fig. 4. Number of wildlife related cases, killings and rescue in Bangladesh during March to June in 2019 and 2020.

incidence of the killing of 200 birds by the villagers for consumption after the cyclone 'Amphan'. Among the wildlife fatality cases, most of the wildlife offences happened in the village forests, followed by hill forests, mangrove forests, and coastal forests (Fig. 5A). The wildlife report was categorised according to broader wildlife groups such as small mammals, birds, big cats, turtles and tortoises, marine species, and ungulates. About half of the identified wildlife fatalities happened among small mammals, such as monkeys (*Macaca mulatta*), Bengal foxes (*Vulpes bengalensis*), followed by ungulates such as spotted deer (*Muntiacus muntjac*), and barking deer (*Axis axis*) (Fig. 5B). The human-wildlife conflict was the topmost cause of wildlife poaching, followed by wildlife trade, human consumption, and psychological reasons (Fig 5C). Among the affected wildlife, both the critically endangered and endangered categories were in the second position, after the top category of least concern from the International Union for Conservation of Nature (IUCN) red list categories (Fig 5D). While monkeys (*M. mulatta*) and Bengal foxes (*V. bengalensis*) from the least concern category were the most killed in the small mammal group, this group also included the critically endangered wildcat (*Felis chaus)*, endangered golden jackals (*Canis aureus*), leopard cats (*Prionailurus bengalensis*) and fishing cats (*Prionailurus viverrinus*), the vulnerable common mongoose (*Herpestes edwardsi*), and near threatened Indian civets (*Paradoxurus Hermaphroditus*) (Table 2). Moreover, common monkeys (*M. mulatta*) and Bengal foxes (*V. bengalensis*) among the small mammals and spotted deer (*M. muntjac*) among the ungulates were hunted at a higher rate during the pandemic in 2020. In addition, nine critically endangered elephants (*Elephas maximus*) were killed in the Cox's Bazar zone in 2020.

3.4. Tourism

Media analysis revealed that the forest-based tourism industry had been affected severely during the COVID-19 pandemic in all protected areas of Bangladesh, including the Sundarbans mangrove forest and the hill forest in Sylhet, as the BFD banned tourism in all the protected areas of Bangladesh. The tourism industry therefore faced severe job cuts and also suffered financial loss during the pandemic. According to the Bangladesh Tourism Board (BTB), the tourism industry in Bangladesh incurred a loss of USD 177 million in the first three months of the pandemic and is also expected to lose more than USD 700 million by the end of 2020 (Hasan, 2020). The tourism industry was affected in the greater Sylhet regions, home of the outstanding hill and swamp forest, where about 10,000 people usually visit daily, as all the parks and tourist destinations were closed (Islam and Islam, 2020). Therefore, people like sailors, tourist guides, and tour agents involved in different sectors such as hotels, restaurants, souvenir shops, and transportation lost their jobs, which has created huge inconvenience and suffering for them. At the same time, the temporary tourism ban has generated some

Table 2
Detailed information on wildlife killings and rescuing in different forest areas of Bangladesh in 2019 and 2020 (26th March −30th June).

Name	Scientific name	IUCN Red List status*	No. Killed	No. Rescued	Forest types		
			2019	2020	2019	2020	
Golden jackal	*Canis aureus*	EN	0	6	0	0	Village forest
Indian civets	*Viverra zibetha*	NT	0	5	1	1	Village forest
Mongoose	*Herpestes edwardsi*	VU	0	3	0	0	Village forest
Elephant	*Elephas maximus*	CE	0	9	0	0	Hill forest
Barking Deer	*Muntiacus muntjac*	LC	0	4	0	0	Village forest
Spotted deer	*Axis axis*	LC	0	13	8	47	Mangrove forest
Monkey	*Macaca mulatta*	LC	0	29	3	0	Village forest
Fishing cat	*Prionailurus viverrinus*	EN	0	6	3	1	Hill forest
Bengal fox	*Vulpes bengalensis*	EN	0	26	0	0	Village forest
Wild cat	*Felis chaus*	CE	2	2	1	1	Village forest
Indian gray wolf	*Canis lupus pallipes*	EN	1	0	0	0	Mangrove forest
Bengal Slow Loris	*Nycticebus bengalensis*	VU	0	0	3	0	Village forest
Leopard cat	*Prionailurus bengalensis*	EN	1	0	0	3	Village forest
Asian Palm Civet	*Paradoxurus Hermaphroditus*	LC	0	0	12	0	Village forest
Capped Langur	*Trachypithecus pileatus*	VU	0	0	1	0	Village forest
Dolphin	*Platanista gangetica*	CE	0	9	0	1	Coastal forest
Indian Roofed Turtle	*Pangshura tecta*	LC	0	0	65	4	Village forest
Total			4	112	97	57	

*EN-Endangered, NT-Near threatened, VU-Vulnerable, CE-Critically endangered, LC-Least concern.

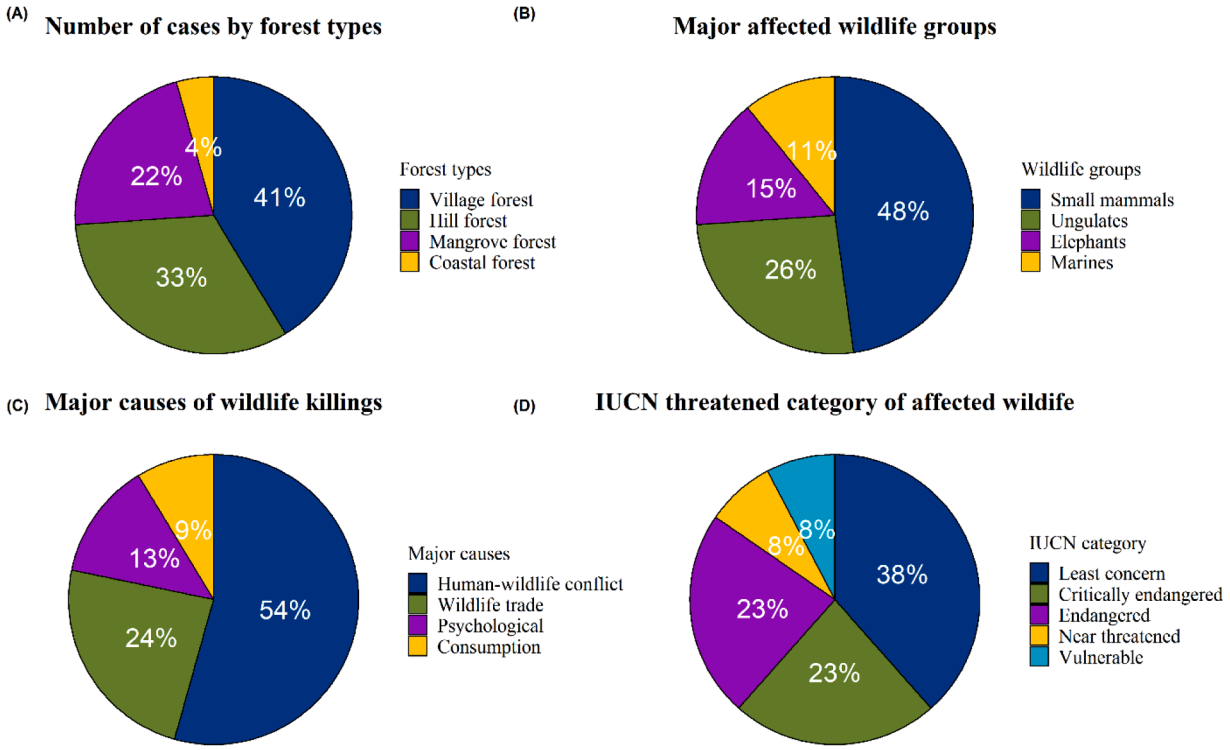

Fig. 5. Pie-chart describing the percentages of (A) cases by forest types in Bangladesh, (B) Major affected wildlife groups, (C) Major causes of wildlife killings and (D) IUCN threatened categories of affected wildlife.

positive impacts on both wildlife behavior, such as the increased movement for mating and breeding, and on the forests, for example, in increased vegetation growth around the sandy beaches. In Kuakata, one of the attractive beaches of Bangladesh, fishes were seen swimming in groups by the shore, red crabs scuttling in the sand, along with a lot of flying birds (Das, 2020). On the Cox's Bazar beach, dolphins and turtles were clearly visible in the water close to shore. Maasranga, a local Television Channel, reported that,

"Wildlife in the Sundarbans Mangrove Forest is coming closer to human and adjacent open spaces because they face no tourist there. The non-existence of engine trawler or boat and ship lead to less noise pollution. As a result, deer, crocodiles and tigers are seen frequently, which was sporadic in the past" (Maasranga, 2020).

3.5. Environmental pollution

Analysis of data from the US embassy, Dhaka, reveals that the mean concentration of particulate matter (PM2.5) of air in Dhaka city decreased by 19% during the lockdown period in 2020, more than that of the same period in 2019 (Fig. 6A). For the gaseous molecules, Sentinel-5P satellite data analysis showed that NO_2, CO, and SO_2 column density (μ mol m^{-2}) decreased by 24%, 2%, and 16%, respectively, during the lockdown period (Fig. 6B–D). Conversely, the O_3 and HCHO column density increased marginally (Fig. 6E & F). A comparison of AAI indicates that the average fell below −0.95 than −0.43 of the same periods of 2019, where negative values indicate lower or no UV (Ultraviolet) radiating aerosol particles in the air (Fig. 6G).

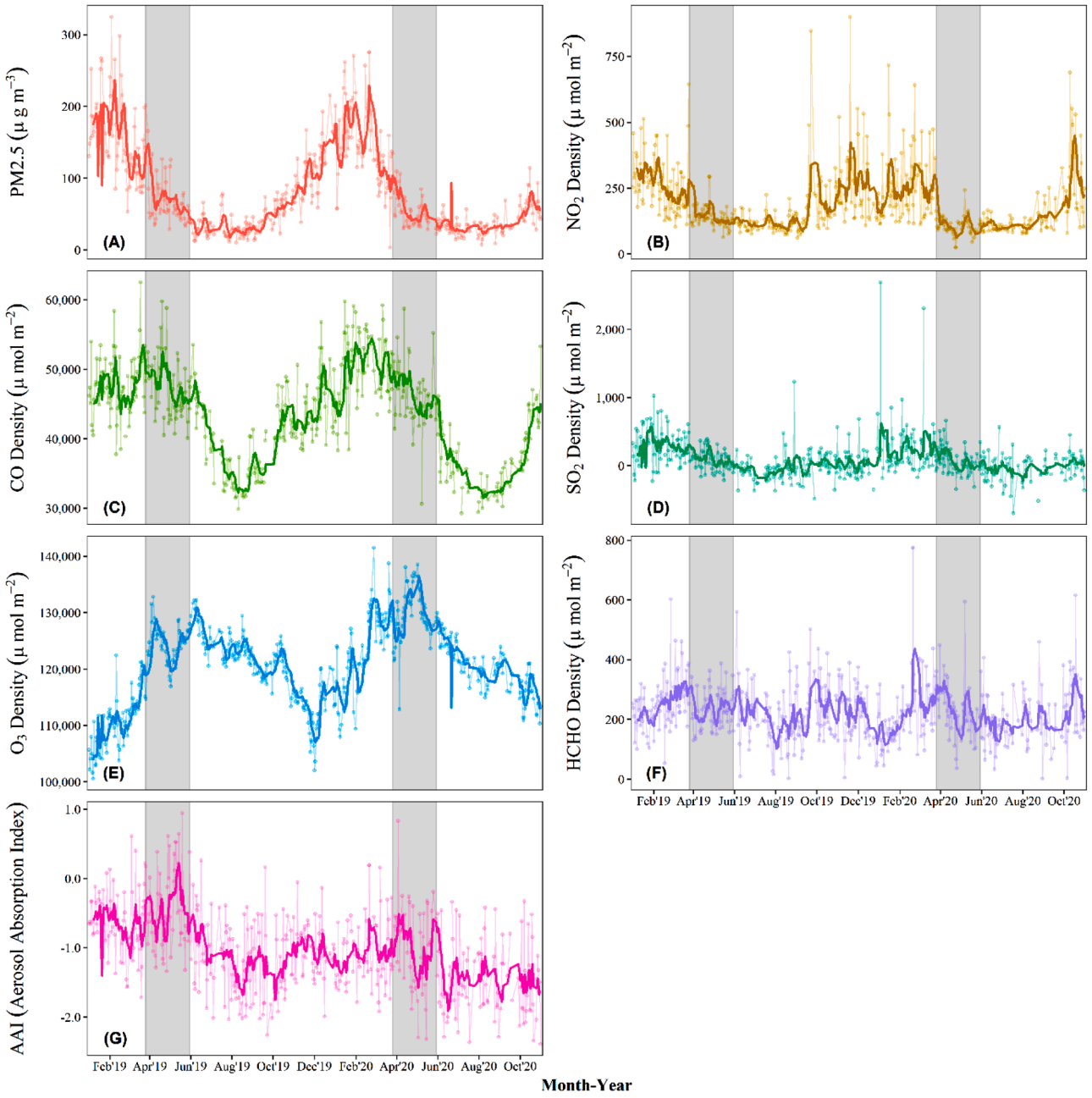

Fig. 6. Daily average PM2.5 and different gaseous molecules in Dhaka city in 2019 and 2020. Light points and lines represent daily average and solid line indicates 7-day moving average. Shaded area represents national lockdown period (26th march to 30th May) in 2020 and the same period in 2019. (A) Particulate matter (PM2.5), (B) NO2 column density, (C) CO column density, (D) SO2 column density, (E) O3 column density, (F) HCHO column density, (G) AAI (UV aerosol absorption index). The unit for (B) to (F) is μ mol m −2 and AAI has no unit (G). N.B.: data in 2020 up to October.

In 2019, a total 19 media reports were found related to environmental pollution in Bangladesh, with the majority (11) related to air pollution, followed by water pollution (4), waste pollution (2), and two for overall pollution. Most of the air pollution reports (10 out of 11) highlighted the status of air pollution in Bangladesh, according to the annual report of Global Air 2019 (Health Effects Institute, 2019). The report also states that since the year 1990, all of Bangladesh has been exposed to PM2.5 levels above 35 μg/m^3, exceeding the WHO guideline. In addition, the rivers of Bangladesh are now heavily polluted from solid and liquid wastes from the encroaching riverbank. These rivers have already exceeded the safety threshold of antibiotic pollution, and they often reach 300 times the concentration of metronidazole, an antibiotic commonly prescribed to people (Borunda, 2019). One Twitter post highlighted that Bangladesh become the 10th globally in plastic pollution, with 0.8 t of plastics dumped into the sea each year.

During the pandemic, reports from several newspapers and social media (17) mentioned the reduced air and waste pollution with the increased activities of plants and animals in the absence of the anthropogenic activities of human beings due to the lockdown. One noticeable positive impact of the lockdown on the environment was less pollution on some beaches, notably Kuakata and Cox's Bazar, due to the reduction of leisure and industrial activities imposed by the national lockdown. The tree density in the coastal forests increased continuously. Reports also indicated that the coral density has increased in the Saint Martin Islands, Bangladesh (Fair, 2020). Six media reports identified a notable reduction of air pollution and improved water quality in and around Dhaka city (Sultana, 2020). The report also added that in addition to reduced movement of people and vehicles on the road, construction

work was closed down, so the particulate matter has reduced substantially. However, 70% of the brickfields surrounding Dhaka city were in operation in April, which kept air pollution higher than expected. Along with the lockdown, the other reason for this remarkable result was the higher rainfall this year and persistent low atmospheric pressure around Dhaka city (Prothom Prothom Alo, 2020).

Despite the notable improvement of air and water pollution and ensured ecosystem health during the lockdown, there have been some threats of greater waste pollution due to excessive dumping of medical waste. For example, two media sources reported dumping of discarded coronavirus safety gear, including masks, gloves, caps, bottles of sanitizer, and personal protective equipment (PPE) in the open spaces, which increases the chance of increased pollution everywhere in the country (Hossain, 2020; Zaman, 2020). Besides pollution, there is also a greater chance of spreading the virus throughout the country. As most of the safety equipment is made of non-biodegradable plastic materials, it creates an increased chance of polluting the water and creating waterlogging in the urban areas by clogging the drainage system.

3.6. Forest products, prices, and revenues

The print media highlighted that forest products, specifically the production of non-timber forest products such as wild honey, have increased in the lockdown period in the Sundarbans mangrove forest. In contrast, revenue from product sale has reduced substantially. The sale of nursery seedlings has reduced by 70% from 2019 to 2020. This finding was in line with the Bangladesh Forest Department (BFD) sector-wise monthly revenue collection report, which showed that revenue collection in all sectors reduced in 2020, compared to the same period in 2019 (Fig. 7). The sale of forest products was by far the most affected sector, followed by income from fixed assets, leases, and fees and fines, respectively.

4. Discussion

Our analysis from various data sources highlighted that there had been conspicuous changes in all investigating parameters, which are likely to have brought enormous suffering to the forest-dependent people and wildlife throughout the country during the COVID-19 mediated lockdown. These changes include increased deforestation, wildlife poaching along with decreased air and water pollution, tourism activities, and revenues to the forest department all together might have both short- and long-term impact on the conservation of forest and wildlife in Bangladesh, as illustrated by Sarkar et al. (2021).

Many indigenous people have a profound cultural and spiritual relationship with ancestral forests. They are the keepers of traditional

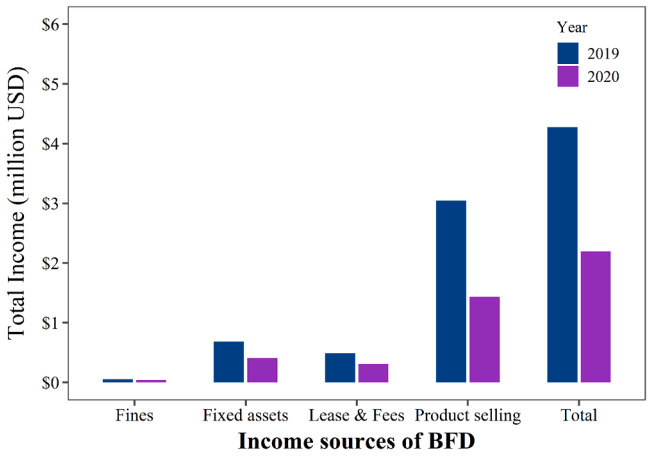

Fig. 7. Total earned revenue by the Bangladesh Forest Department (BFD) from different sources between March to June in both 2019 and 2020.

knowledge on forest biodiversity, much of which is at risk of being lost (FAO and UNEP, 2020). Forests, throughout the world, have served as a source of safety nets for the rural poor and forest-dependent communities, especially in crises, including the COVID-19 pandemic (FAO, 2020a). Amongst the extreme poor in rural areas, around 40% live in the forest and nearby areas (Sen, 2020). Forest products provide food, income, and nutritional diversity for about 20% of the global population, especially women, children, tenant farmers, and other vulnerable societies (FAO, 2020a; WHO, 2021). Around 2.4 billion people-one-third of the world's population-still rely on wood fuel to meet their basic energy needs (Sen, 2020; UN, 2020a). The COVID-19 pandemic has suddenly transformed the lives of all Bangladeshis (FAO, 2020b) and created a dilemma of whether to save lives from the deadly viruses through continuing lockdowns or livelihoods by removing lockdown restrictions and social distancing (Sharma and Mahendru, 2020). Within this dilemma, the lockdown has imposed a severe social and economic toll (Bhuiyan et al., 2020; Shammi et al., 2020), which has negatively impacted on the livelihoods of the poor and vulnerable communities near the forest. As a result, it is predicted that poverty and food insecurity will increase, especially in the emerging and developing nations, for short to medium term (Brancalion et al., 2020).

Moreover, the disrupted supply chain and decreased income-generating activities have resulted in an outward population migration from urban to rural areas, which is one of the main reasons for over-harvesting of forest biodiversity and degradation of natural resources (FAO, 2020b; Golar et al., 2020). The pandemic has also brought significant changes in the human behavioural and psychological condition to the people, which probably increase human-wildlife conflict (Bodrud-Doza et al., 2020). The human-wildlife conflict is the results of a broader range of social and psychological considerations such as diverse cultural and emotional experiences, economics, governance, stakeholder engagement and human-human conflict (Clark et al., 2014; Decker et al., 2012; Inskip et al., 2014; Treves and karanth, 2003).

The increasing deforestation in the hill forest in 2019 and 2020 has been a continuing phenomenon in the Chattogram hill forest since 1930 (Reddy et al., 2016; Potapov et al., 2017). However, the recent recurrence of deforestation in the hill forest can largely be attributed to the destruction of the natural forests in the Cox's Bazar region by the Rohingya refugees, who fled to Bangladesh from Myanmar in August 2017 (UNDP Bangladesh and UN WOMEN Bangladesh, 2018). Along with the ongoing destruction of natural and village forests, the national strategies at the beginning of the pandemic might have exerted economic and social pressure on the forest-dependant people leading to deforestation and degradation of the natural forest in Bangladesh. Worldwide empirical studies suggest that poverty always constitutes a major pressure on forest ecosystems, including rural trees and wildlife, and increasing population density and rural poverty portend badly for conserving natural areas (Geist and Lambin, 2003; Miyamoto, 2020). The demand for firewood collection from the neighbouring forest might be exaggerated due to disruption of the supply chain of alternative energy options and decreasing household income opportunities (UN, 2020a). Moreover, illegal loggers might take the opportunity of scaled back law enforcement by the forest officials or other law enforcing agencies. Similar things happened in Brazil, Colombia, Cambodia, Indonesia, Nepal, and Madagascar, where illegal loggers invaded the indigenous forest land leading to soaring deforestation rates during COVID-19 (Fair, 2020). In Brazil, deforestation in the first four months of 2020 climbed to 55% more than in 2019, which is the greatest since 2008 (Butler, 2020). After analysing GLAD data throughout the tropics, Brancalion et al. (2020) found a total of 9583 km^2 of deforestation alerts during the first month of the COVID-19 pandemic, which is nearly double that of 2019.

The COVID-19 has impacted the tourism sector heavily in Bangladesh. The country is heavily dependent on tourism, with an extraordinary 944 related jobs for every 100 visitors or nine jobs for every tourist (Madden, 2020). According to the World Travel and

Tourism Council, in 2019, Bangladesh's travel and tourism industry contributed 3.0% of the total economy and created 1858 new jobs, 2.9% of the total employment (WTTC, 2020). Closure of natural areas such as national parks, safari parks, sanctuaries, and other tourist attractions, national and international travel bans, canceled conferences, festivals, concerts, and wide-spread restrictions on public gatherings and community mobility have largely terminated interest in tourism (Hafsa, 2020; Saadat et al., 2020; Gössling et al., 2021). The COVID-19 pandemic has brought a significant long-term impact on both inbound and outbound tourism activities in Bangladesh, with substantial economic losses and employment cuts (Deb and Nafi, 2020). After analysing the returns of five listed tourism companies, Chowdhury (2020) found that both COVID-19 positive cases and restrictions on movement had a significant impact on the stock return, implying deterioration of the normal flow of tourism business in Bangladesh. The impact of curtailed tourism might create the opportunity for illegal hunters to kill the animals, as evident in the Lawachara National park in North-East Bangladesh (Sultana, 2020). However, a German study teaches us differently, showing soaring forest visitor numbers during the lockdown, thus revealing forests as part of the critical infrastructure during a pandemic, which has implications for forest policy, especially in urban areas (Derks et al., 2020). Global analysis by Geng et al. (2020) also reveals that park visitation has increased during the pandemic more than in 2019, strengthening the demand for an increased number of parks and outdoor green areas in urban settings.

Illegal poaching, trafficking, and trading of wild animals is not a new phenomenon in densely populated developing countries like Bangladesh, where a large portion of poor people live beside the forests and earn their livelihoods from forest resources (Mahtab and Karim, 1992; Salam and Noguchi, 1998; WCS, 2018). Despite the government's dedicated efforts to prevent these crimes, news about poaching and rescuing wild animals is quite common in Bangladesh (Naher et al., 2017; Reza and Hasan, 2019). However, this lockdown has given it a new dimension and exacerbated the problem because of the restriction in movement and activities of law enforcement staff and agencies, which have greatly encouraged wildlife criminals. The rate of wildlife poaching (28 per month) during the pandemic has been seven times higher than the five-year rate (4.15 per month) estimated by WCS (2018). Increased animal poaching, trading, and trafficking due to the lockdown have already been reported from other parts of the world, such as Africa, Russia, South America, and South-East Asia, since the first spread of the virus (Badola, 2020; Ghosal and Casey, 2020; Price, 2020; Maron, 2020a). Our findings in Bangladesh follow the same trends as in other South-Asian countries such as India, Pakistan, Nepal, and Sri Lanka, where a record number of cases of wild animal poaching and trading has been noted during the lockdown period (Badola, 2020; Islambad, 2020; Rodrigo, 2020). Also, this region, including India, Nepal, Bangladesh, Myanmar, Thailand, and China, is one of the most active wildlife trafficking routes, which use Bangladesh as a transit point (Krishnasamy and Zavagli, 2020). It seems they are taking advantage of this lockdown and increasing their illegal activities. However, other causes, such as cyclone 'Amphan', flooding, Rohingya influx, and inland and marine pollution, could have overlapped with the pandemic time, leading to increased wildlife fatalities along with the pandemic related intervention (Jalais and Mukhopadhyay, 2020).

The reduced number of rescued animals in this study during the lockdown indicates decreased activity from government officials of the wildlife crime control unit, e.g., reduced patrolling in the protected areas. Small mammals have frequently been killed in this period, mainly in the villages and hill forests, where the wildlife attacked livestock or crops, presenting as a human-wildlife conflict. Moreover, deer were killed in the Sundarbans mangrove forest solely for meat consumption. The rising poverty level is one of the main reasons for wildlife crime as the pandemic caused the economic shutdown, which has made many people lose their jobs and thereby, the unemployment rate has increased dramatically (Hamadani et al., 2020; Mamun and Ullah, 2020; Sakamoto et al., 2020). While suffering from poverty and at the same time lack of forest protection and surveillance, it is believed that people have easily got access to the protected areas and extracted resources such as plants and animals for food, fuel, and trade.

The air quality parameter during the pandemic has reduced in most cases compared to the same period in 2019. Rahman et al. (2021) also found a 20–55% reduction of PM2.5 and NO_2 levels in Dhaka city compared to pre-lockdown times. However, air quality in Bangladesh mostly follows a seasonal pattern with higher concentrations during the dry season (January to March) and starts to decline with the onset of precipitation in April (Islam et al., 2020). Therefore, comparing the parameters with the same period in the previous year's possibly provide the actual outcome of any intervention. Data from different parts also reported a similar reduction of air quality parameters in different cities. Compared to the previous year, the air quality parameter in 20 cities of India was reduced for PM10, PM2.5, NO_2, and CO by 43%, 31%, 18%, and 10%, respectively (Sharma et al., 2020). A range of studies documented a similar reduction of air quality parameters across different megacities in the world, such as China (Wang and Su, 2020; Zhang et al., 2020), Malaysia, and other Southeast Asian countries (Kanniah et al., 2020), Spain (Baldasano, 2020) and Iraq (Hashim et al., 2021). However, the improvement of air quality in Dhaka city was comparatively less pronounced than other cities in the world as other sources like brick and biomass burning were in operation. Improvement of water quality and subsequently, increasing the activity of endangered dolphins is also documented in the major polluted river, such as Ganga (India) (Khan, 2020). Similarly, endangered Olive Ridley sea turtles and rare Leatherback sea turtles were also seen in Odisha, India and Thailand (Sarkar et al., 2021). On the other hand, extensive use and dumping of protective gear, such as masks, gloves and other safety equipment, has increased solid waste pollution in different parts of the world (Zambrano-Monserrate et al., 2020). However, the overall short-term reduction of both Greenhouse gas (GHG) emissions and air pollutants could bring immediate cooling but is negligible for offsetting long-term warming (Forster et al., 2020).

The reduced revenue collection by the Forest Department can be the result of COVID-related interventions brought by the government. The complete closure of tourism activities, travel bans, and reduced official activities by the forest department may have adversely affected the revenue during the pandemic time. The closure of offices, markets, and other income-generating services significantly affects the price of forest products and employment opportunities for rural communities (Mamun and Shawon, 2020). However, honey production has increased in the Sundarbans mangrove due to reduced human disturbance to the ecosystem. This increased honey production brought higher income to the honey collectors and increased revenue to the BFD.

We acknowledge the limitation of the study for not collecting any ground data to verify the remote sensing information under the circumstances posed by COVID-19 and the travel restrictions imposed by the Bangladesh government. We also declare that the number of actual wildlife killings may vary as many incidents might not be documented in the media. Alternatively, the media might have been more active, mainly during the pandemic collecting such news. The novel coronavirus pandemic has not only proved to be damaging to forests and wildlife in Bangladesh, but has also negatively affected education and research, which will impact the conservation of natural areas of Bangladesh (Corlett et al., 2020). Nature conservation might be treated as 'non-essential' and would likely face a budget crisis due to the massive economic fallout from the pandemic and prioritizing essential expenditure to the health sectors and reinvigorating the livelihood of the people. After investigating governments economic stimulus packages during the pandemic, Kroner et al. (2021) found rollback for environmental protection in 64 cases from 22 countries, especially in the protected and conserved areas. This budget cut will surely hamper the ongoing and planned nature conservation and protection activities in different forest areas in Bangladesh. Under the adverse circumstances wrought by the

COVID-19 pandemic on forest and wildlife conservation in Bangladesh, national and international activities and treaties will likely be hampered. In particular, all 17 goals set for the United Nations Sustainable Development Goal (SDG) would be threatened under the socio-economic and environmental fallout wrought by the COVID-19 pandemic (Irfanullah, 2020; (UN, 2020b). The target set by national policies such as National Forest Policy, (proposed), the Eighth Five Year Plan (8FYP) for 2021–2025, and the Perspective Plan for 2021–2041 could also be threatened from being achieved on time.

Worldwide the COVID-19, as predicted, is becoming a recurrent threat in many countries, including Bangladesh (Everard et al., 2020). Together with wildlife and habitat destruction, the short-term negative impact on the environment would seriously affect the conservation of forest resources in the long run (Neupane, 2020). Although pandemic brought immense pressure to the livelihood, increased pressure on poaching, destruction of habitat and financial uncertainty for conservation activities, at the same time, it brought many opportunities to make better decisions for nature conservation. The recent international ban on trading and consumption of wildlife by the Chinese government would reduce the wildlife trade from Bangladesh (Koh et al., 2021). The reduction of anthropogenic activities in the core area of forests will benefit the wildlife in an interim period. However, it is anticipated that conservation efforts would be minimised due to the reduction of foreign aids and disruption of research activities. Therefore, the government of Bangladesh should take immediate step to tackle the COVID-19 pandemic and focus on the ongoing drivers of deforestation, such as Rohingya influx in the hill forest (Mukul et al., 2019), Addressing forest degradation drivers, such as development activities close to the Sundarbans is also essential to conserve forests and wildlife in Bangladesh (Mukul et al., 2020a).

5. Conclusion

The present study was designed to determine the effect of national emergency actions at the beginning of the COVID-19 pandemic on forest and wildlife conservation and the forest-dependent people in Bangladesh. Despite some improvement in air and water quality and wildlife movement, data from a variety of sources revealed that this pandemic caused an unprecedented upheaval to the socio-economic condition of forests, forest-dependent communities, and tourism industries, leading to a higher rate of deforestation and wildlife poaching in all forests in Bangladesh, with a higher degree in the village and hill forests. The findings indicate that the degradation and deforestation have increased during the COVID-19 pandemic due to lower surveillance and lack of tourism activities. The vulnerable people depended on the adjacent forests most for their livelihoods during the burdensome lockdown. The return to normality from the pandemic outbreak would significantly impact the ongoing and future forest and wildlife conservation in Bangladesh. Therefore, the Bangladesh government and the Forest Department need to pay careful attention to short and long-term COVID-19 recovery policies, with the aspiration towards sustainable and healthy forest ecosystems and resilient forest-dependent communities.

5.1. Policy recommendations

The Bangladesh government should establish post-COVID-19 recovery programmes focusing on the livelihoods of forest-dependent rural and indigenous communities, and people involved in the tourism industry. A remarkable recovery plan to revive and foster the tourism industry is essential.

The government should encourage and enhance the participation of non-governmental organisations and the people to be involved in conservation activities in different forests in Bangladesh. The establishment of an online system to report illegal cases would enhance the monitoring capabilities of the forest department.

The Forest Department should consider halting deforestation and wildlife poaching as a top priority in their policy agenda. In this regard, the department should be innovative in using social media and modern technology. For example, real-time satellite imagery would be an excellent option to monitor deforestation and wildlife poaching. In addition to the wise application of existing legal measures, mass awareness campaigns should be strengthened to protect forest biodiversity, especially at the grassroots level.

In addition to the COVID-19 pandemic, the Forest Department should be deliberative in their policies by prioritizing various critical drivers of deforestation and wildlife loss to safeguard the forest ecosystems, especially in the village and hill forests.

The Forest Department should consider urban forestry as a priority by scaling up afforestation and reforestation programs and ramping up conservation of biodiversity rich critical areas, in order to establish green landscapes in the cities.

It is vital to consider seasonal or temporary banning of human activities to ensure free movement of wildlife and their uninterrupted breeding under strict monitoring.

The Forest Department should prioritize national targets and undertake enabled policies in liaison with the UN Strategic Plan for Forests 2030 and the UN Sustainable Development Goals (SDGs).

Establish a dashboard on the Forest Department's website to produce and publish timely data regarding the status of forests, deforestation, wildlife poaching and rescuing, and the targets set by national and international policies and treaties. This initiative will facilitate understanding of the base line situation, monitor progress and perform research to attain targets for sustainable forest management in Bangladesh.

Declaration of Competing Interest

None

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